



# Nanoporous Membrane Technologies for Pathogen Collection, Separation, and Detection

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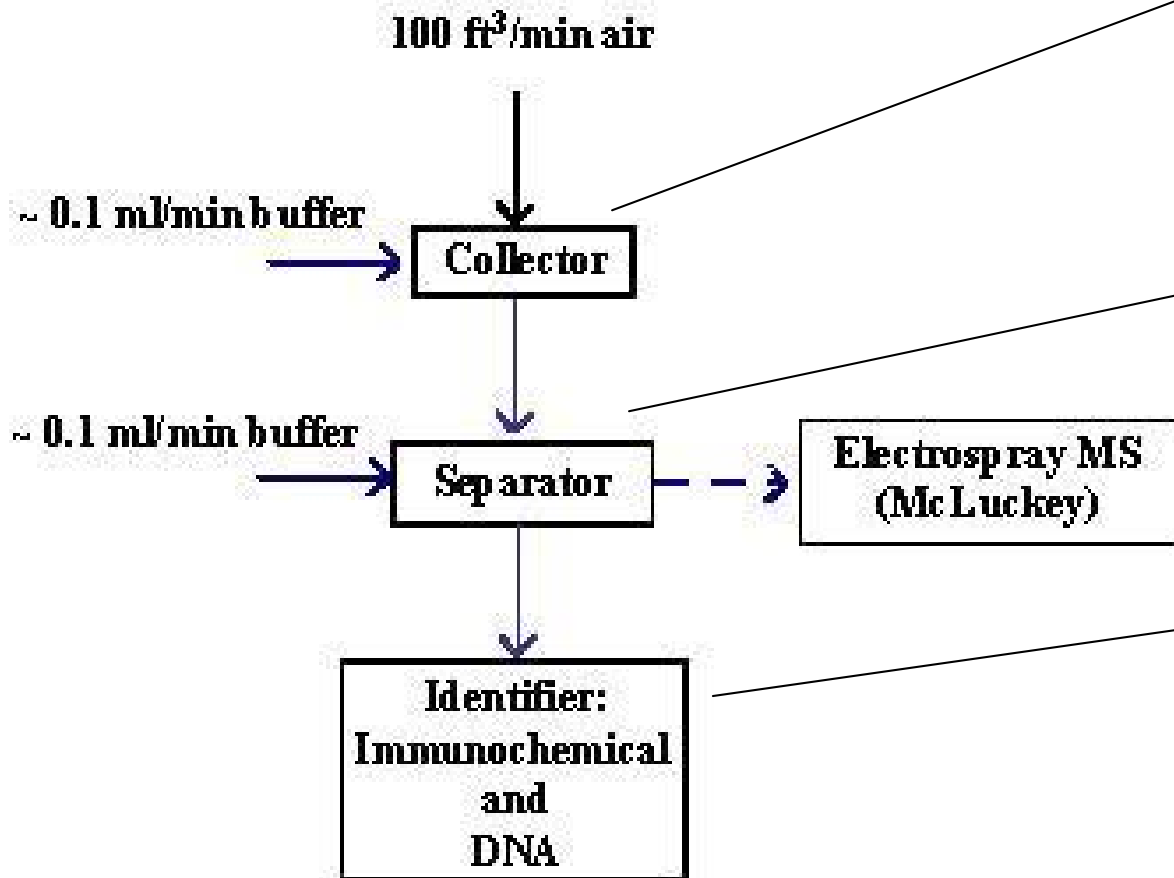
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# Approach

## Schematic of a Point Detector that Utilizes Membrane



Develop membranes and methodology for continuous collection of airborne particles.

Develop a membranes and methodology for continuous separation via ultrafiltration. Develop a receptor functionalized membrane to improve mass transport and kinetic conditions.

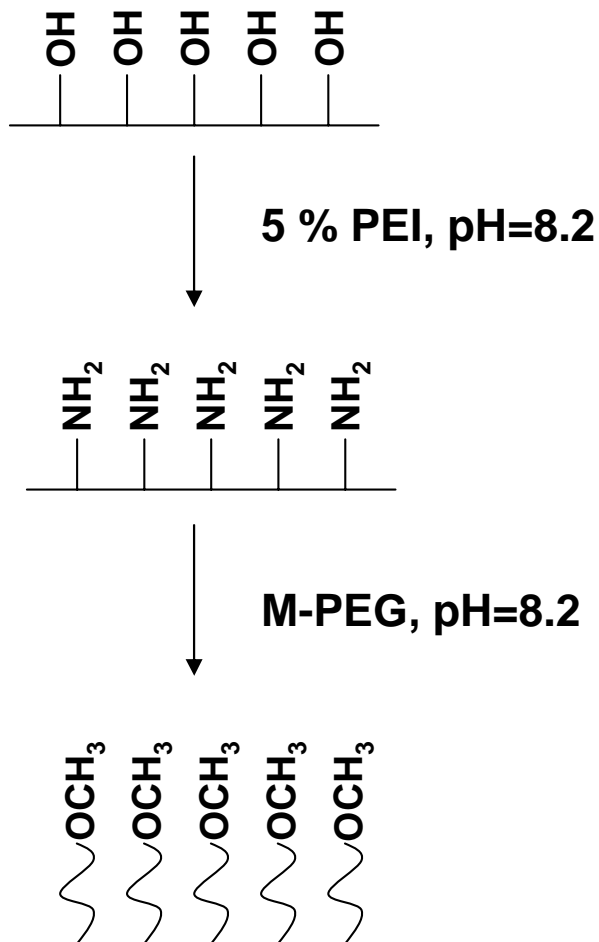
# Nanoporous Membranes



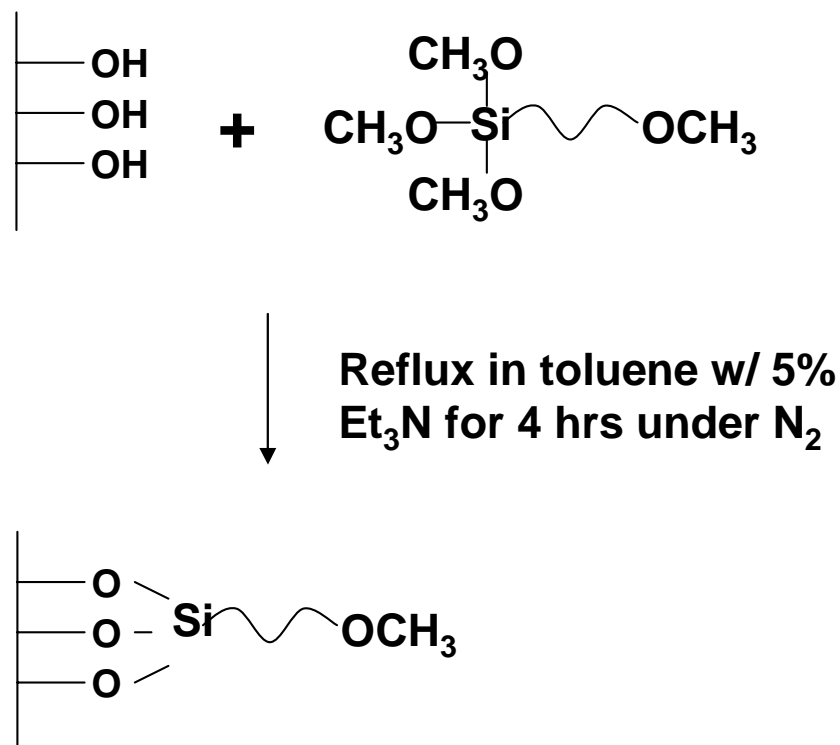
- Nanoporous alumina membranes were chosen as a substrate because of their desirable physical properties and high density of uniform pores of 10-200 nm size.
- The membrane surfaces will be modified with hydrophobic and hydrophilic coatings to facilitate pathogen collection and separation.
- The membrane surfaces will be modified with proteins and nucleic acids to enable pathogen identification.

# Membrane Chemistries

## PEI-PEG (2000)



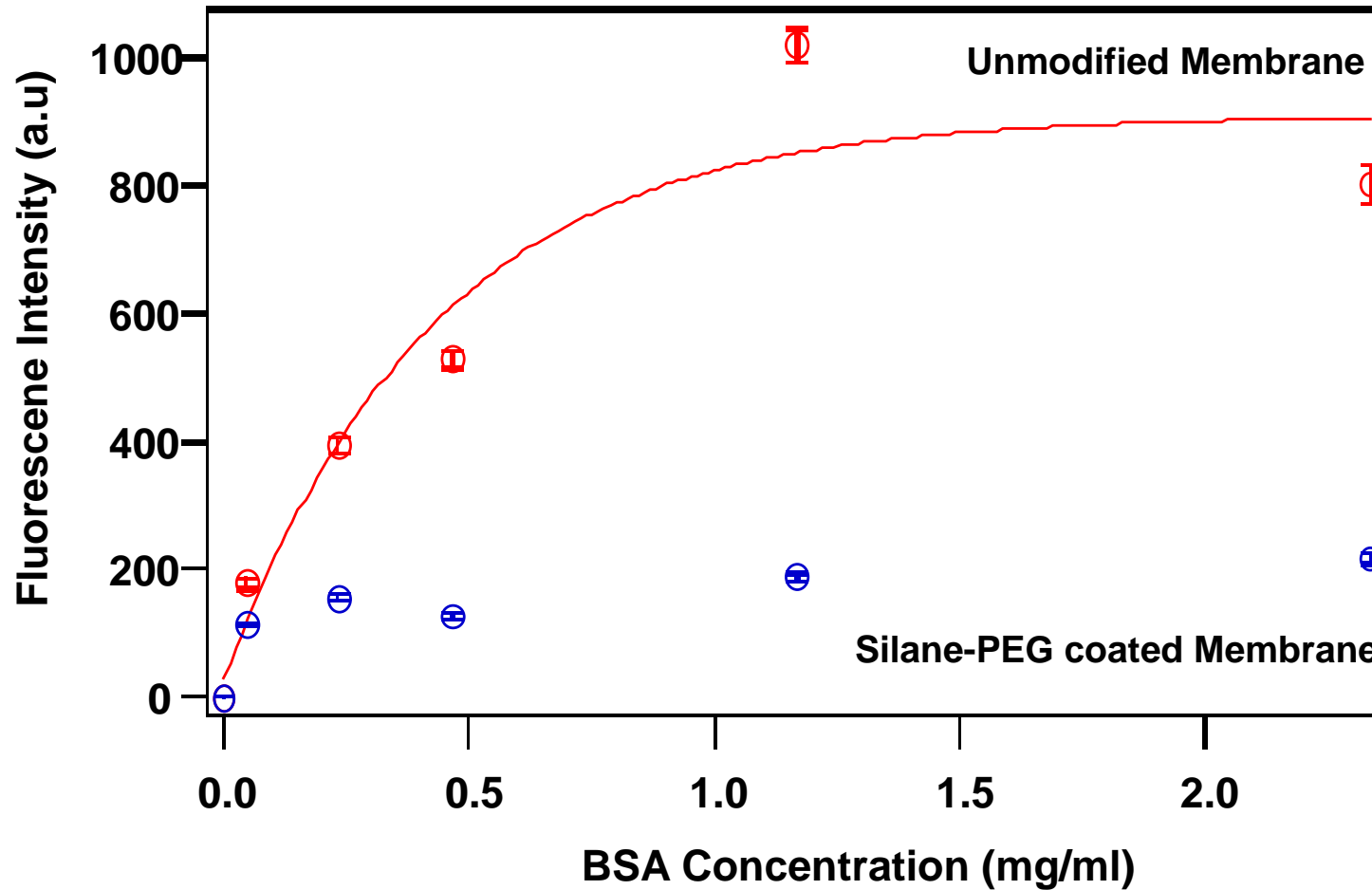
## Silane-PEG (5000)



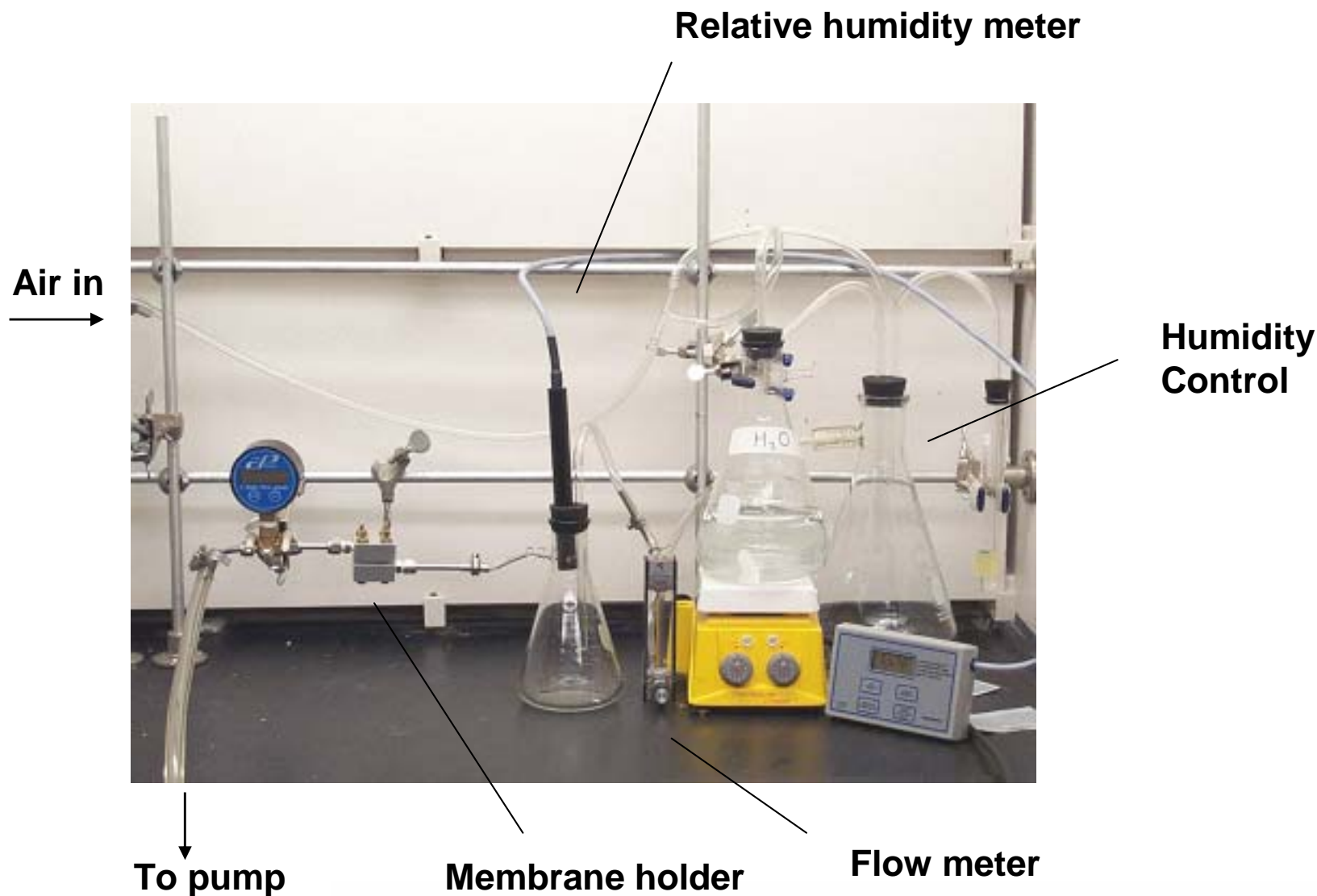
## Characterization of Membrane Chemistries

Chemistry	% Al 2p (74.4 eV)	% Si 2p (103.5 eV)	% C 1s (285.6 eV)	% C 1s (286.5 eV)	% N 1s (399.1 eV)	% O 1s (530.3 eV)	% O 1s (532.0 eV)
Unmodified membrane	30.3	—	11.1	—	—	58.4	
PEI	19.2	—	33.2	—	12.2	35.8	—
PEI-PEG	5.0	—	9.0	50.2	5.6	11.0	21.0
OTMS coating	24.5	1.2	35.8	—	—	38.6	—
Silane- PEG	11.0	2.1	—	46.4	3.4	15.3	21.8

# Protein Fouling



# Collector



# Gas and Liquid Permeabilities

Nitrogen permeability (m/PaS)

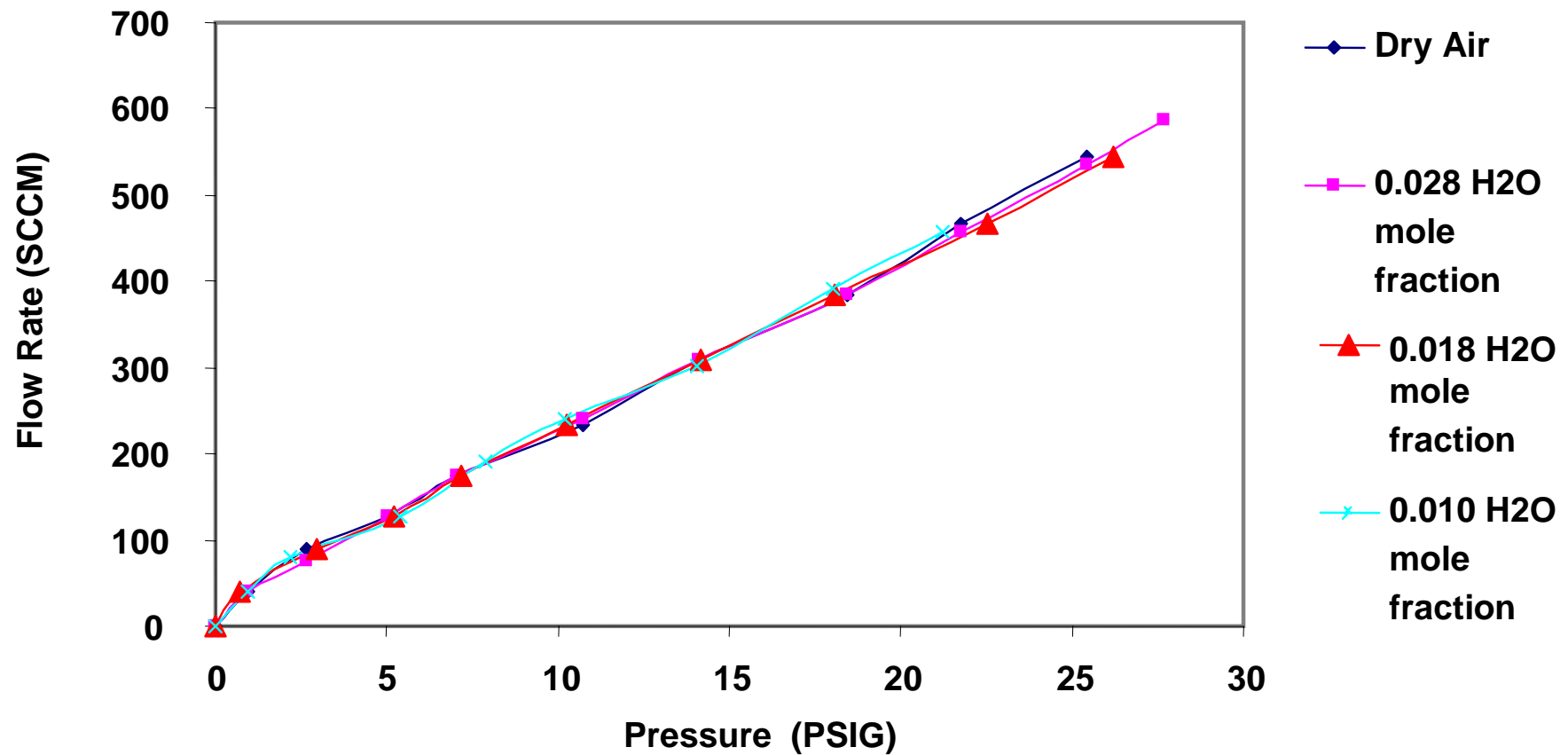
	Bare membrane		PEI	PEG	Silane-PEG
	Holder 2	Holder 1			
20 nm	1.98E-06	1.90E-06	2.0E-06	7.08E-08	2.03E-06
100 nm	4.62E-06	6.08E-06	4.63E-06	3.14E-06	-
200 nm	6.50E-06	6.88E-6	-	-	6.84E-06

Water permeability (m/PaS)

	Bare membrane		PEI	PEG	Silane-PEG
	Holder 2	Holder 1			
20 nm	7.00E-09	2.67E-09	1.64E-09	Fouling	6.59x10 <sup>-09</sup>
100 nm	1.91E-08	2.14E-08	n/a	Fouling	-
200 nm	2.86E-08	2.18E-08	3.04E-09	4.06E-10	2.73E-08



## Membrane Permeabilities in the Presence of Water





# Operation Characteristics

## Collection Efficiency

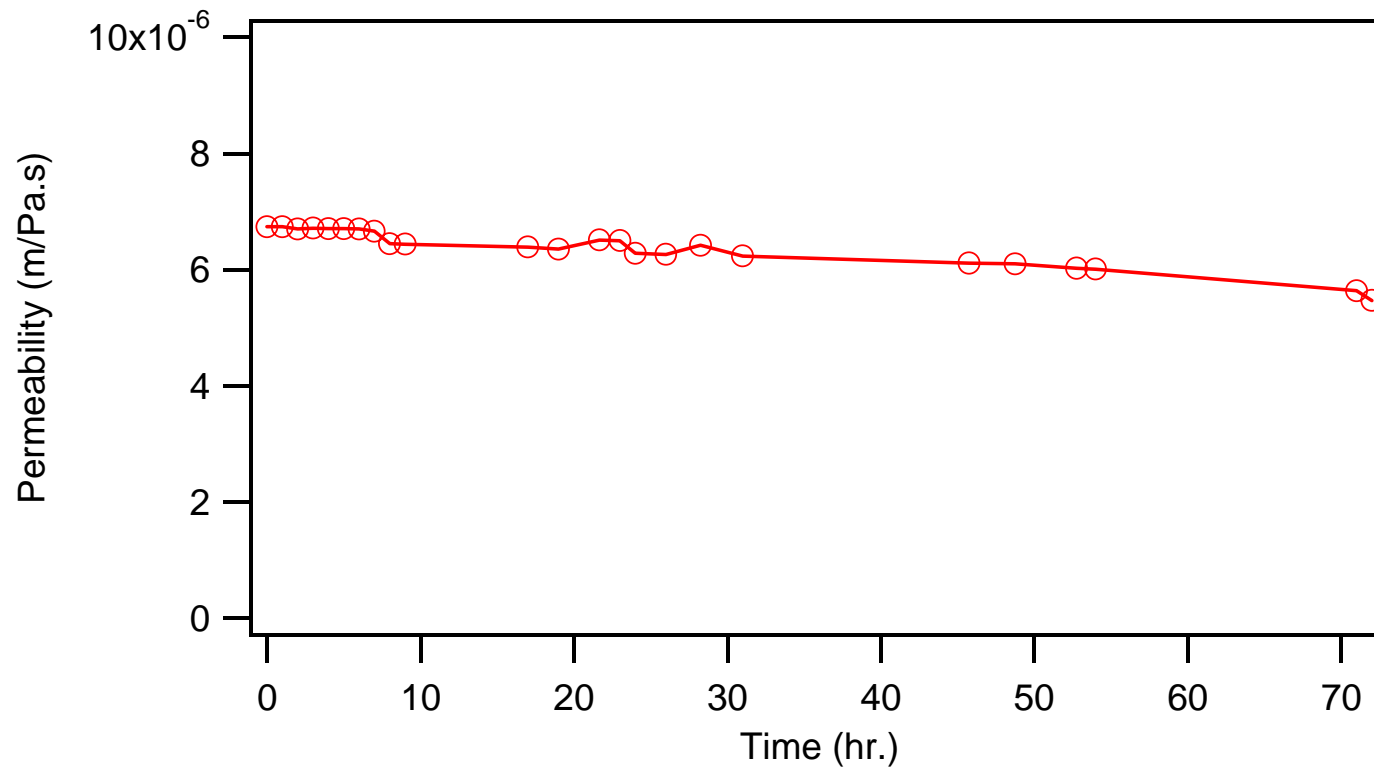
	BG spores (spores/ml)
Before	$2 \times 10^6$
After filtration	0

## Extraction Efficiency

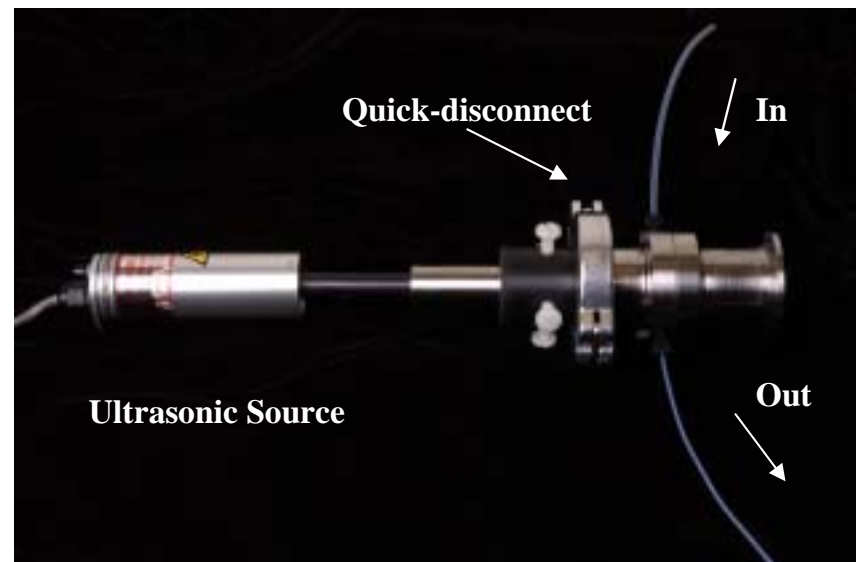
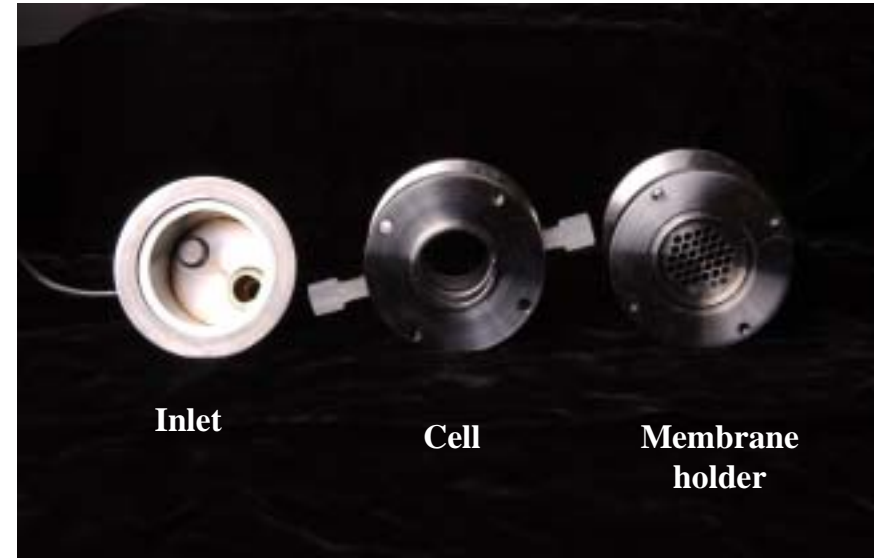
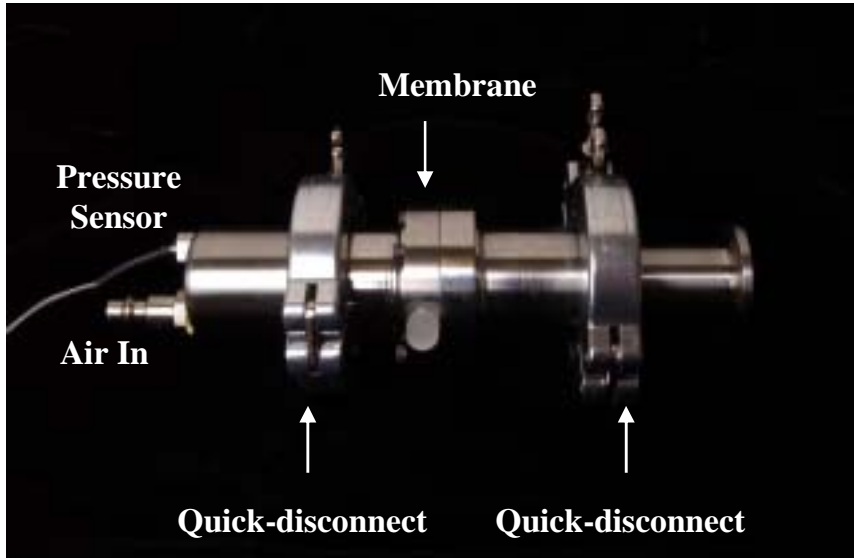
Method of Extraction	Removal Efficiency (%)
PBST 0.5 %	75.4
SDS 10 %	76.4
H <sub>2</sub> O	26.9
Sonication in PBS	96.7



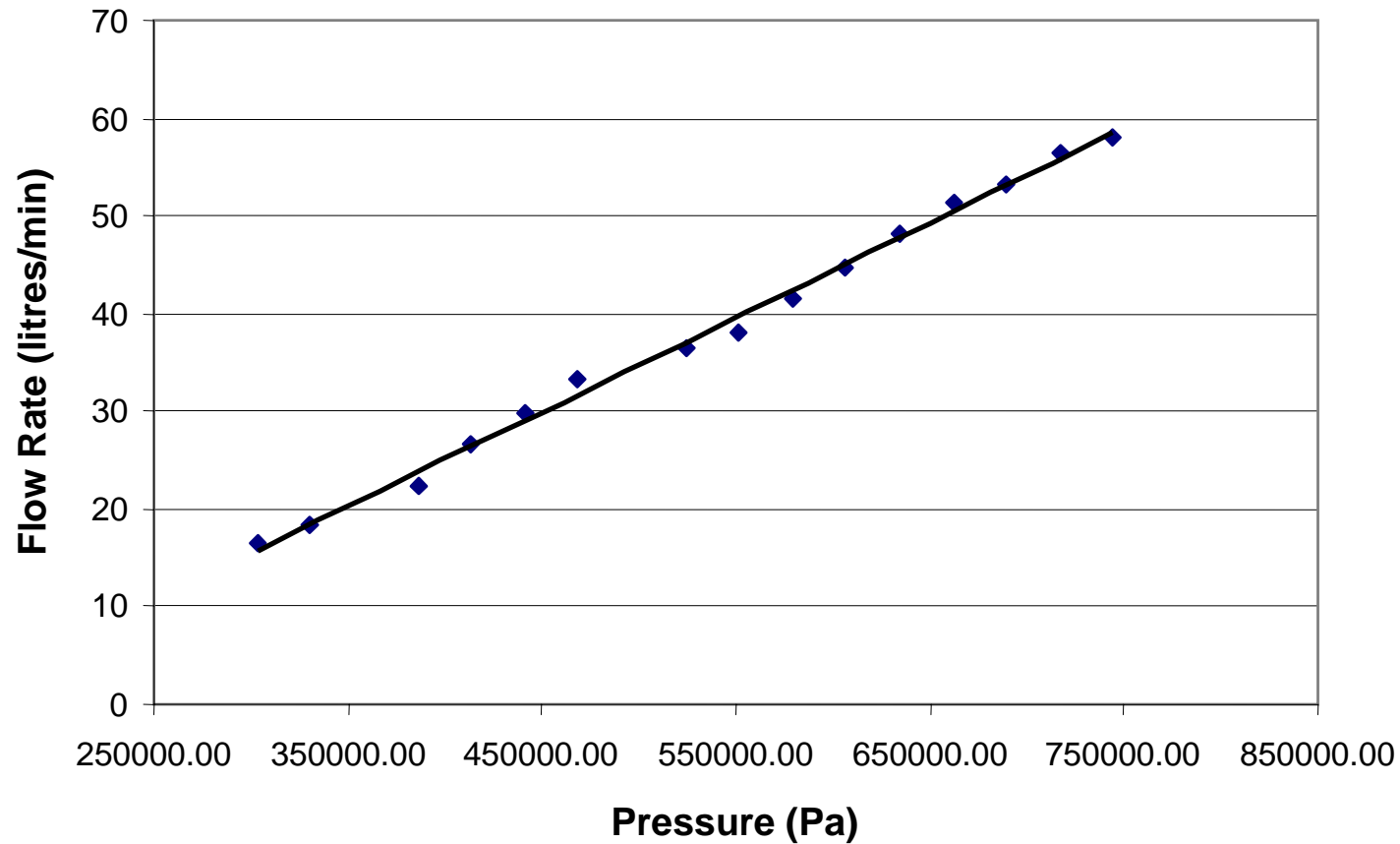
# 3 Day Laboratory Trial



# Collector Prototype

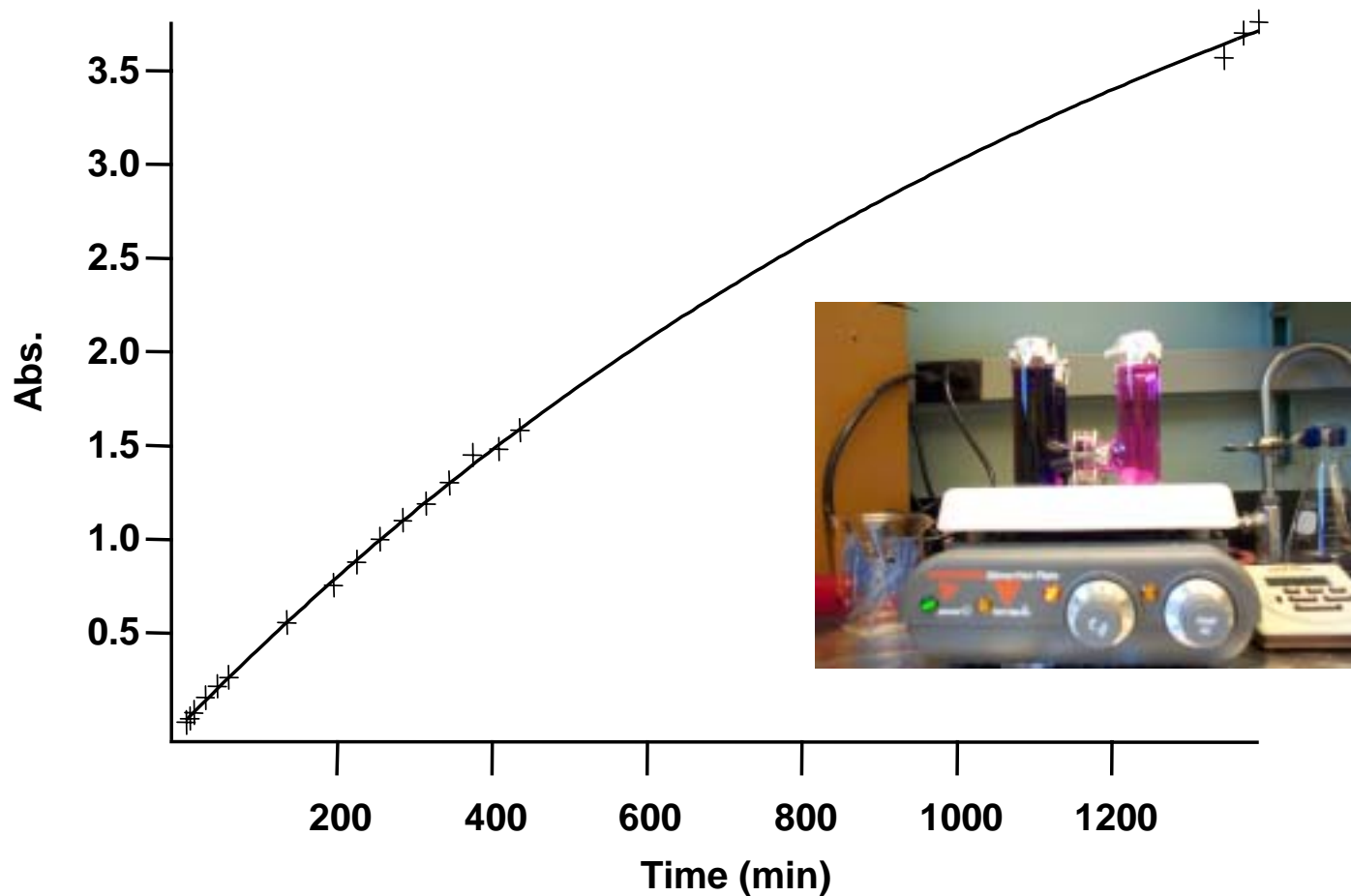


# Performance of the Prototype



# Separator - Solute Permeabilities

20nm membrane

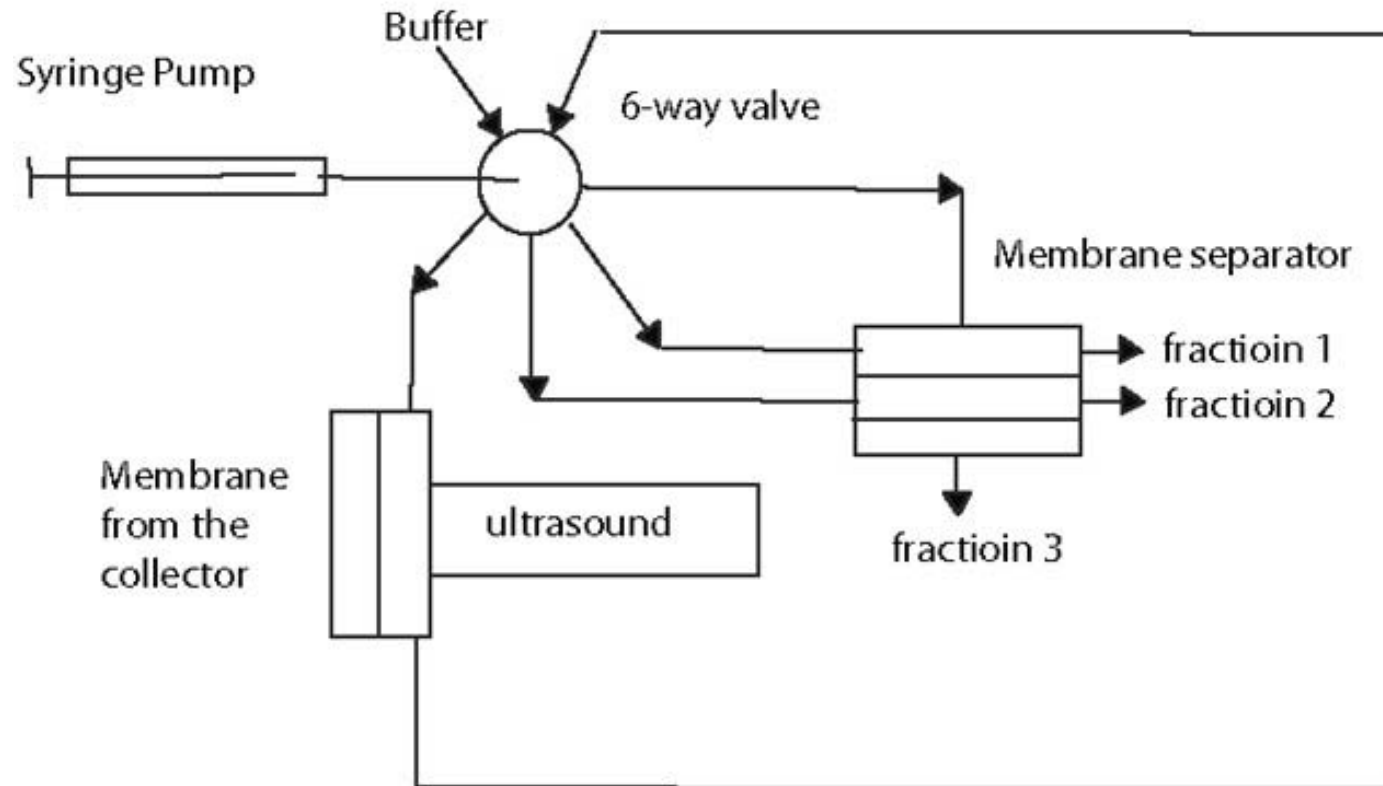


# Protein Permeability

Theoretical Permeability of Ovalbumin (cm <sup>2</sup> /s)	Unmodified Membrane	PEI-PEG	Silane-PEG
6.37x10 <sup>-7</sup>	8.19x10 <sup>-7</sup>	0	7x10 <sup>-7</sup>

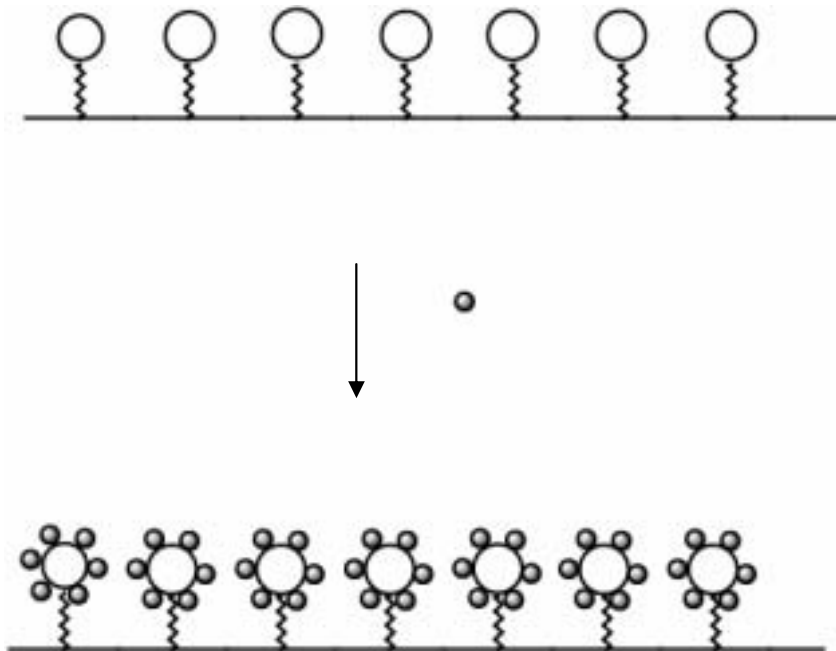


# Collector & Separator Fluidics

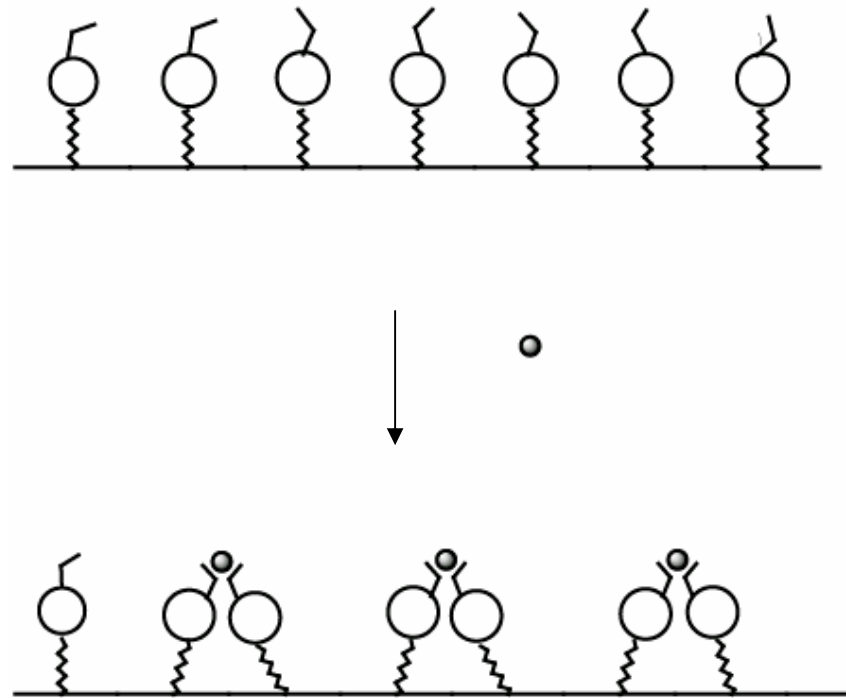


# Detection

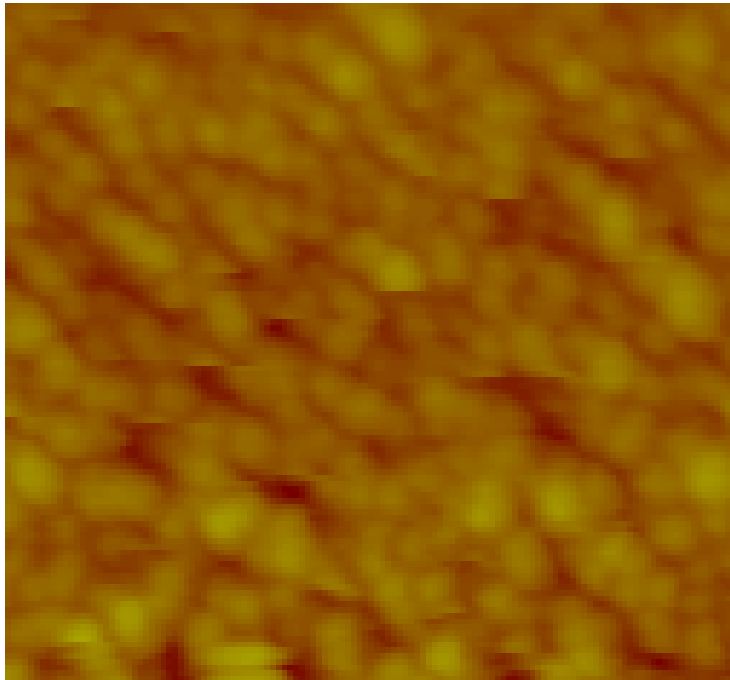
## Adsorption



## Scattering



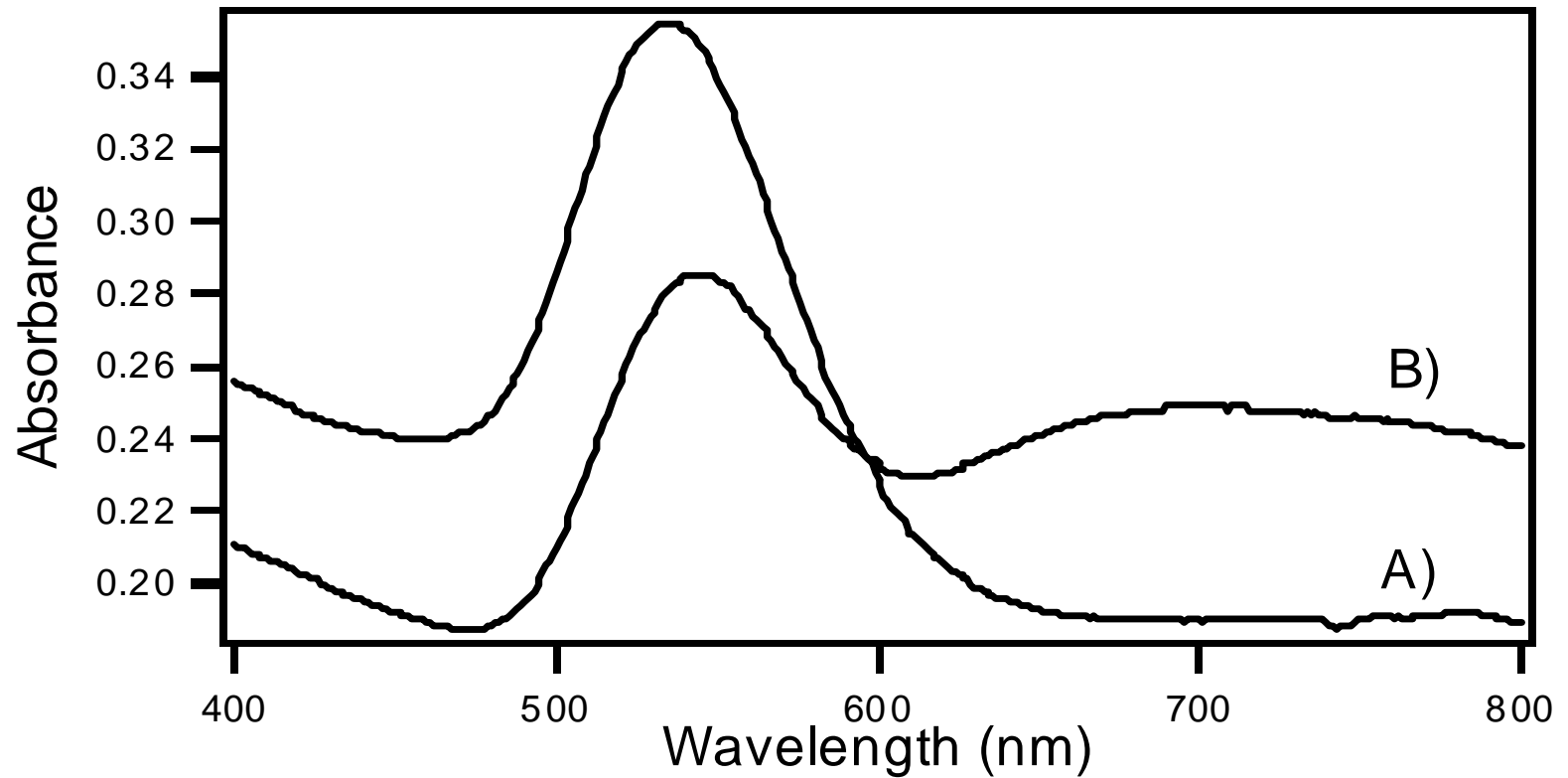
# Self-assembled Monolayers



Atomic force microscope image of a 12 nm Au array. Scan size 500 x 500 nm. Z scale 50 nm

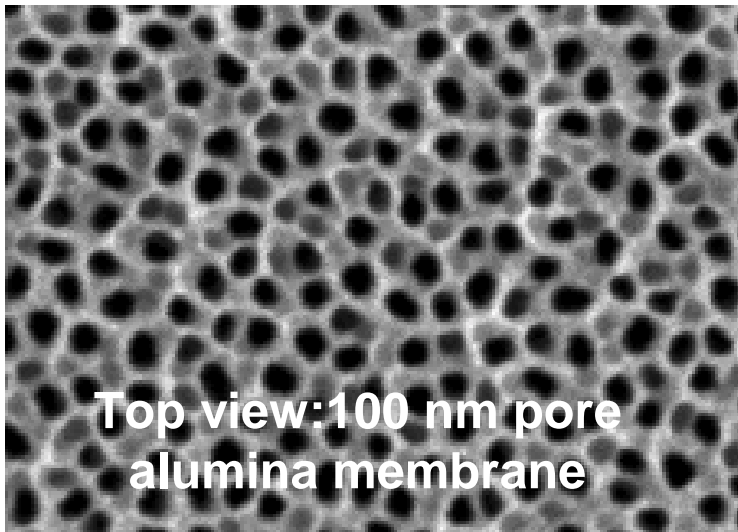


# Ovalbumin Binding



# Nanoporous Membrane Separation Methodologies

**Objective:** To fabricate and characterize the performance nanoporous membranes for the collection, separation, and detection of airborne pathogens.



**Payoff:** A highly sensitive point detector that consumes minimal reagents. Design criteria include < 0.1 ACPLA sensitivity for toxins, viruses and bacteria; < 10 min response time; < 0.5 ml/min total reagent consumption.

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